COMPARISONS BETWEEN MIX DESIGNS TOWARDS SF-OPSC MECHANICAL PROPERTIES

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ABSTRACT

Oil Palm Shell (OPS) is a waste lightweight aggregate originating from the palm oil industry. In this study, OPS was used as coarse aggregate. This research investigate the comparison between mix designs towards the Steel Fiber Oil Palm Shell Concrete (SF-OPSC) mechanical properties with similar concrete strength. The objectives of this study are determine the effect of different mix designs to the behaviour of SF-OPSC and study the mechanical properties of SF-OPSC. The testing specimen are cube, cylinder and prism specimens. The size of cube is 100 mm x 100 mm x 100 mm, cylinder with 150 mm in diameter and 300 mm in height and prism with the cross-section of 100 mm x 100 mm and 500 mm in length. The concrete grade that is used is 25 MPa. The tests that are conducted are compressive strength test, flexural strength test, tensile strength test and modulus of elasticity test. The type of fiber that is used is hooked end steel fiber. The volume fraction of SF is same which is 1%. The mix designs used are different in W/C; which are 0.58 and 0.62. The amount of OPS aggregate that are used in the specimen are 50% and 100%. Results shows that W/C does influenced the mechanical properties of SF-OPSC. The compressive strength of SF-OPSC increased with the increasing of W/C. While, the flexural strength increased with the increasing of W/C. Other than that, the splitting tensile strength of SF-OPSC decreased with the increasing of W/C. Finally, the W/C does influenced the modulus of elasticity of SF-OPSC.

ABSTRAK

Tempurung Kelapa Sawit (OPS) adalah sisa agregat ringan yang berasal daripada industri minyak sawit. Dalam kajian ini, OPS telah digunakan sebagai agregat kasar. Kajian ini menyiasat perbandingan di antara reka bentuk campuran ke arah Konkrit Gentian Keluli Tempurung Kelapa Sawit (SF-OPSC) sifat mekanik dengan kekuatan konkrit yang sama. Objektif kajian ini adalah menentukan kesan reka bentuk campuran yang berbeza untuk tingkah laku SF-OPSC dan mengkaji sifat mekanik SF-OPSC. Spesimen ujian kiub, silinder dan prisma spesimen. Saiz kiub adalah 100 mm x 100 mm x 100 mm, silinder dengan 150 mm diameter dan 300 mm tinggi dan prisma dengan keratan rentas 100 mm x 100 mm dan 500 mm panjang. Gred konkrit yang digunakan ialah 25 MPa. Ujian yang dijalankan adalah ujian kekuatan mampatan, ujian kekuatan lenturan, ujian kekuatan tegangan dan ujian modulus keanjalan. Jenis gentian yang digunakan merupakan gentian keluli hujung bercangkuk. Pecahan jumlah SF adalah sama iaitu 1%. Reka bentuk campuran yang digunakan adalah berbeza dari segi W / C; iaitu 0.58 dan 0.62. Jumlah OPS agregat yang digunakan di dalam spesimen tersebut adalah 50% dan 100%. Keputusan menunjukkan bahawa W/C tidak mempengaruhi sifat mekanik SF-OPSC. Kekuatan mampatan SF-OPSC meningkat dengan peningkatan W/C. Walaupun, kekuatan lenturan meningkat dengan peningkatan W/C. Selain daripada itu, kekuatan tegangan SF-OPSC menurun dengan peningkatan W/C. Akhir sekali, W/C tidak memperngaruhi kekuatan modulus keanjalan bagi SF-OPSC.

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LIST OF SYMBOLS

σ	Stress
F	Force
A	Area
E	Modulus of Elasticity
ε	Strain

LIST OF ABBREVIATIONS

BS	British Standard
LWA	Lightweight aggregate
LWAC	Lightweight aggregate concrete
MPa	Mega Pascal
OPS	Oil palm shell
OPSC	Oil palm shell concrete
SF	Steel fiber
SF-OPSC	Steel fiber oil palm shell concrete
SFRC	Steel fiber reinforced concrete
W/C	Water cement ratio

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Concrete is widely used as a construction material. Therefore, there is no escaping from the influenced of concrete in everyday life. It is estimated that the present consumption of concrete in the world is of the order of ten billion tonnes every year. Concrete is a composite material composed mainly of water, aggregate and cement. Usually there are admixtures and reinforcements included to achieve the desired properties of the finished products. When these compositions are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone.

Cement is a finely pulverized, dry, material that by itself is not a binder but develops the binding property as a result of hydration. Water is responsible for the hydration reactions with the cement. Aggregate is the granular material, such as sand, gravel, or crushed stone that is used with a cementing medium to produce either concrete or mortar. Meanwhile, admixtures are defined as materials other than aggregates, cement, and water, which are added to the concrete batch immediately before or during mixing. The use of admixtures in concrete is now widespread due to many benefits which are possible by their application.

However, these primary materials can be replaced with others to obtain or to develop a more sustainable concrete. It has been reported that oil palm shell (OPS) can be used as replaced aggregate in concrete. Since OPS is an organic material, its properties differ from that of conventional granite aggregates. OPS is lightweight in nature and has bulk density of about 590 kg/m^3 (Teo *et al*., 2009). Consequently, the resulting concrete is lightweight. OPS aggregate can be used as an alternative to the conventional granite aggregates for the production of lightweight concrete. The utilization of OPS as aggregate replacement in concrete is a good way of practicing sustainable development (Teo *et al*., 2009).

Steel fibers (SF) with different yield strengths are available in various shapes and sizes which improves the mechanical properties of the concrete in a wide range. Addition of SF changes the workability of the concrete and also balling of these fibers in concrete may occur depending on the amount and shape of the fiber used (Tadepalli *et al*., 2009). SF are available in various shapes namely straight, crimped, hooked single, hooked collated and twisted. Among the fibers, hooked fibers performs better than straight and crimped SF in terms of flexural strengths and energy absorption capacities (Bayasi *et al*., 1992).

1.2 PROBLEM STATEMENT

The environmental impact of oil palm cultivation is a highly controversial topic. OPS are agricultural solid end products of oil palm manufacturing processes. Palm trees grow in regions where the temperature is hot with copious rainfall such as Malaysia, Indonesia, and Nigeria. The utilization of OPS as lightweight aggregate (LWA) in the production of lightweight aggregate concrete (LWAC) has been a topic of research since the early 1984 in Malaysia. OPS are one of the wastes produced during palm oil processing. Figure 1.1 shows the oil palm efficiency compared to the other major oil crops.

Recently, a large amount of OPS waste materials are stockpiled and dumped, which causes storage problems within the vicinity of factories as large quantities of these wastes are produced every day. In Malaysia, it is estimated that over 4.6 million tonnes of OPS is produced annually as waste. A cost analysis in Nigeria revealed that a cost reduction of 42% is possible for concrete made from OPS. Several studies showed that although the engineering properties of oil palm shell concrete (OPSC) are generally satisfactory, there is still reluctance in implementing OPSC compared with other types of LWAC. The reason for this was given by Okafor., 1988 who concluded that OPS are incapable of producing concrete with a compressive strength above 30 MPa (Ming *et al.*, 2014).

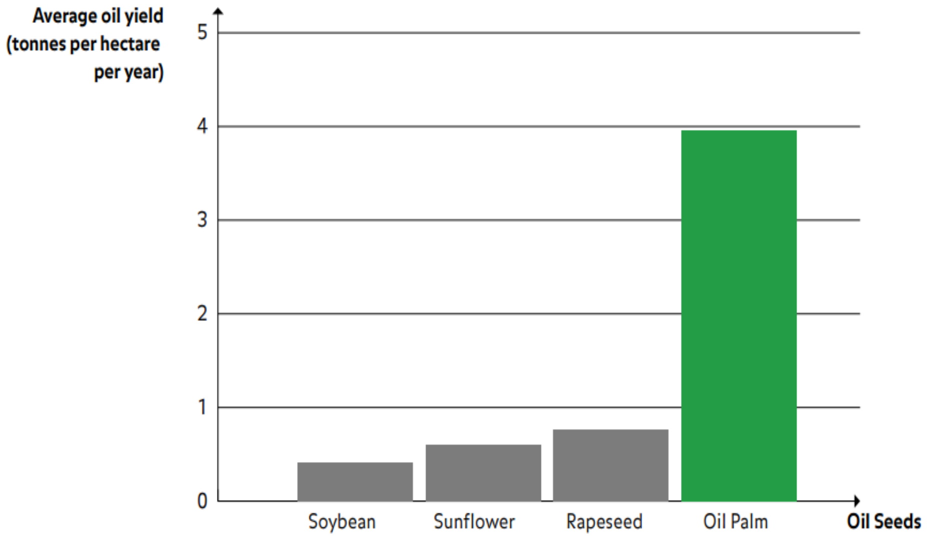

Figure 1.1: Oil palm efficiency compared to the other major oil crops

Due to the higher amount of oil palm shell wastes, we can create something that useful to the public by using this kind of wastes for example the OPSC reinforced with SF. This solution will provide a good strength of reinforced concrete.

1.3 RESEARCH OBJECTIVES

The objectives of this research are :

i. To determine the effect of different mix designs to the behaviour of steel fiber oil palm shell concrete (SF-OPSC).
ii. To study the mechanical properties of SF-OPSC.

1.4 SCOPE OF STUDY

The scopes of this study are :

i. Testing specimen of cube, cylinder and prism specimens
ii. The size of cube is 100 mm x 100 mm x 100 mm, cylinder with 150 mm in diameter and 300 mm in height and prism with the cross-section of 100 mm x 100 mm and 500 mm in length

iii. The concrete grade that is used is 25 MPa

iv. The tests that are conducted are slump test, compressive strength test, flexural strength test, tensile strength test and modulus of elasticity test

v. The type of fiber that is used is hooked end steel fiber

vi. The volume fraction of SF is same which is 1%

vii. The mix designs that will be used are different in W/C which are 0.58 and 0.62

viii. The amount of OPS aggregate that are used in the specimen are 50% and 100%

1.5 RESEARCH SIGNIFICANCE

The expected outcomes from this research is on the improvement of OPS and SF when inside the structural element. Besides that, we can investigate the mechanical properties when the steel fiber and oil palm shell were in lightweight concrete and get the knowledge about it. It is economical to use OPS in the lightweight concrete because of the higher amount of OPS wastes.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

OPS is considered as a waste material produced from the extraction of palm oil in South East Asian countries, such as Indonesia, Malaysia, and Thailand (U. Johnson *et al.,* 2014). In Malaysia, OPS is an agricultural solid waste originating from the palm oil industry. The Palm Oil Industry is a significant industry in the Malaysian economy. This country currently accounts for 51% of world palm oil production and 62% of world exports. Almost 80% of the volume from the processing of the fresh fruit bunch is removed as waste (P. Shafigh *et al.*, 2012). OPS is one of the wastes produced during the palm oil processing. Recently, plenty of OPS waste, as a lignocellulosic material, was obtained due to the increasing number of plantations of oil palm trees. It was estimated that over 4.56 million tonnes of waste OPS is produced annually (P. Shafigh *et al*., 2012).

The applications of agricultural wastes as aggregate or cement replacement material in concrete have engineering potential and economic advantage. Each of the agricultural waste consists of physical and chemical properties. Solid agricultural waste as coarse aggregate together with cement matrix can meet design specifications in low-cost lightweight structures (M. A. Mannan *et al*., 2004).

In palm oil mills, the hard shells are directly attained by breaking the palm karnel shells by using the machinery. Usually, OPS aggregates are composed of different shapes as shown in the Figure 2.1. Before using the OPS aggregate in concrete, pre-treatment is necessary because it contains dust and oil coating. The processes are :

(i) partial oxidation of organic aggregate, (ii) waterproofing, (iii) neutralisation with alkali or precipitation of tannates, or sulphate treatment, (iv) mixing with lime or calcium chloride for better performance of concrete as an accelerator, (v) micro organism treatment of aggregate by boiled water with ferrous sulphate, and (vi) removing oil coating with detergent and water (M. A. Mannan *et al*., 2004).

Steel fiber-reinforced concrete (SFRC) is concrete made of hydraulic cements containing fine and coarse aggregate and discontinuous discrete steel fibers. Addition of randomly distributed steel fibers improves concrete properties, such as static flexural strength, ductility and flexural toughness. Many researchers have shown that the impact resistance can be increased substantially with the addition of randomly distributed steel fibers to concretes (Zhang *et al*., 2014). Since the invention of SFRC in 1874, it has become a useful structural material since 1970's, mainly because the addition of steel fibers significantly improves the mechanical properties of concrete, including impact strength, toughness, flexural strength, tensile strength, ductility and the ability to resist cracking and spalling (Chen *et al*., 2014).

Figure 2.1: Sample of OPS aggregate

2.2 FIBER

2.2.1 Background of Fiber

Plain concrete is a brittle material with low tensile strength and low tensile strain and hence requires reinforcing material to be used as a structural member. Currently, continuous steel fiber distributed appropriately has been used as the reinforcing material to improve tensile strength (Lee *et al.,* 2014).

Due to the weakness of concrete in tensile, fiber is introduced. Fibers are not only discontinuous, but they also end up distributed irregularly in the concrete. Therefore, fiber reinforcements do not effectively resist tensile stress. However, fibers are effective at controlling cracking included in a concrete element because the distance between the fibers is less than the distance between the steel rebar sections. Therefore, if both fiber and steel rebar are used as reinforcing materials, this helps to enhance the load-bearing capacity of the concrete, and the fiber will effectively control cracking (Lee et al., 2014).

The fiber can be divided into many types for example natural fiber, synthetic fiber and steel fiber. These are elaborated more in next sections.

2.2.2 Types of Fiber

2.2.2.1 Natural Fiber

The natural fibers, abundantly available in nature and also generated from agricultural waste. They can be used in improving certain physical properties of concrete, eventhough the durability of resultant mix is relatively poor. As compared to the fibers widely used in construction activities viz. Steel, glass carbon synthetic and others, these are advantageous in the sense that they are renewable, non abrasive, cheaper, comparatively more flexible and others. Also, the health and safety concerns during their handling, processing and mixing are less. Several natural fibers have been used in research works. Their objectives are on investigating and improving the mechanical properties of concrete matrices which are brittle in nature (Srivastava *et al*., 2013).

The natural fibers potentially to be used as reinforcement in concrete to overcome some inherent deficiencies of these materials. These fibers are advantageous as compared to widely used artificial fibres because they are cheaper, renewable, non abrasive, abundant and do not create health and safety problems during handling, processing and mixing operations. The fibers includes coconut, sugarcane bagesse, banana, san, date-palm, coir, eucalyptus, flax, bamboo, agava, elephant grass, roselle, palm oil and others (Srivastava *et al*., 2013). The types of natural fibers are shown in the Figure 2.2.

The cotton fiber grows on the seed of a various of plants of the genus *Gossypium*. Of the four cotton species cultivated for fiber, the most important are *G. hirsutum*, which originated in Mexico and produces 90% of the world's cotton, and *G. barbadense*, of Peruvian origin, which accounts for 5%. World average cotton yields are around 800 kg per hectare. Cotton is almost pure cellulose, with softness and breathability that have made it the world’s most popular natural fiber. It absorbs moisture readily, which makes cotton clothes comfortable in hot weather, while high tensile strength in soap solutions means they are easy to wash. An estimated 60% of cotton fiber is used as yarn and threads in a wide range of clothing, most notably in shirts, T-shirts and jeans, but also in coats, jackets and foundation garments. Cotton is also used to make home furnishings, such as draperies, bedspreads and window blinds, and is the most commonly used fiber in sheets, pillowcases, towels and washcloths. The cotton fiber is shown in the Figure 2.2 (a).

Jute is extracted from the bark of the white jute plant, *Corchorus capsularis* and to a lesser extent from tossa jute (*C. olitorius*). It flourishes in tropical lowland areas with humidity of 60% to 90%. A hectare of jute plants consumes about 15 tonnes of carbon dioxide and releases 11 tonnes of oxygen. Yields are about 2 tonnes of dry jute fibre per hectare. Jute has high insulating and anti-static properties, moderate moisture regain and low thermal conductivity. During the Industrial Revolution, jute yarn largely replaced flax and hemp fibres in sackcloth. Today, sacking still makes up the bulk of manufactured jute products. Jute yarn and twines are also woven into curtains, chair coverings, carpets, rugs and backing for linoleum. Blended with other fibres, it is used in cushion covers, toys, wall hangings, lamp shades and shoes. Very fine threads can be separated out and made into imitation silk. Jute is being used increasingly in rigid packaging and reinforced plastic and is replacing wood in pulp and paper. Geotextiles made from jute are biodegradable, flexible, absorb moisture and drain well. They are used to prevent soil erosion and landslides . The jute fiber is shown in the Figure 2.2 (b).

Sheep are shorn of their wool usually once a year. After scouring to remove grease and dirt, wool is carded and combed, then spun into yarn for fabrics or knitted garments. Merino sheep produce up to 18 kg of greasy wool a year. Wool has natural crimpiness and scale patterns that make it easy t spin. Fabrics made from wool have greater bulk than other textiles, provide better insulation and are resilient, elastic and durable. Fiber diameter ranges from 16 microns in superfine merino wool to more than 40 microns in coarse hairy wools. Wool is a multifunctional fibre with a range of diameters that make it suitable for clothing, household fabrics and technical textiles. Its ability to absorb and release moisture makes woollen garments comfortable as well as warm. Two thirds of wool is used in the manufacture of garments, including sweaters, dresses, coats, suits and active sportswear. Blended with other natural or synthetic fibres, wool adds drape and crease resistance. Slightly less than a third of wool goes into the manufacture of blankets anti-static and noise-absorbing carpets, and durable upholstery. Wool's inherent resistance to flame and heat makes it one of the safest of all household textiles). Industrial uses of wool include sheets of bonded coarse wool used for thermal and acoustic insulation in home construction, as well pads for soaking up oil spills. The wool fiber is shown in the Figure 2.2 (c).

Coir is extracted from the tissues surrounding the seed of the coconut palm (*Cocos nucifera*). There are two types of coir which are brown fiber, which is obtained from mature coconuts, and finer white fiber, which is extracted from immature green coconuts after soaking for up to 10 months. Coir fibers measure up to 35 cm in length with a diameter of 12-25 microns. Among vegetable fibers, coir has one of the highest concentrations of lignin, making it stronger but less flexible than cotton and unsuitable for dyeing. The tensile strength of coir is low compared to abaca, but it has good resistance to microbial action and salt water damage. White coir spun into yarn is used in the manufacture of rope and it is strong resistance to salt water, in fishing nets. Brown coir is used in sacking, brushes, doormats, rugs, mattresses, insulation panels and packaging. The coir fiber is shown in the Figure 2.2 (d).

Abaca is extracted from the leaf sheath around the trunk of the abaca plant (*Musa textilis*), a close relative of the banana, native to the Philippines and widely distributed in the humid tropics. Harvesting abaca is labourious. Each stalk must be cut into strips which are scraped to remove the pulp. The fibres are then washed and dried.

Abaca is a leaf fiber, composed of long slim cells that form part of the leaf's supporting structure. Lignin content is 15% high. Abaca has great mechanical strength, buoyancy, resistance to salt water damage, and long fiber length up to 3 metres. The best grades of abaca are fine, lustrous, light beige in colour and very strong. During the 19th century abaca was widely used for ships' rigging, and pulped to make sturdy manila envelopes. Today, it is still used to make ropes, twines, fishing lines and nets, as well as coarse cloth for sacking. There is also a flourishing niche market for abaca clothing, curtains, screens and furnishings. The abaca fiber is shown in the Figure 2.2 (e).

Silk is produced by the silkworm, *Bombyx mori*. Fed on mulberry leaves, it produces liquid silk that hardens into filaments to form its cocoon. The larva is then killed, and heat is used to soften the hardened filaments so they can be unwound. Single filaments are combined with a slight twist into one strand, a process known as filature or silkreeling. A silk filament is a continuous thread of great tensile strength measuring from 500 to 1500 metres in length, with a diameter of 10 to 13 microns. In woven silk, the fiber's triangular structure acts as a prism that refracts light. It has good absorbency, low conductivity and dyes easily. Silk's natural beauty and other properties such as comfort in warm weather and warmth during colder months have made it sought after for use in high-fashion clothes. It is used in sewing thread for high quality articles, particularly silk apparel, and in a range of household textiles, including upholstery, wall coverings and rugs and carpets. The silk fiber is shown in the Figure 2.2 (f).

(a) cotton

(b) jute

(c) wool

(d) coir

(e) abaca

(f) silk

Figure 2.2: Types of natural fibers